Mechanical Engineering Design Guide

• Introduction

The Appendix “A” defines the scope of A&E services. This Mechanical Engineering Design Guide further defines the mechanical engineering services identified in the Appendix “A” and identifies our technical and submittal requirements for mechanical engineers doing design work for the LANTNAVFACENGCOM.

• Communications

Direct communication with the LANTNAVFACENGCOM mechanical reviewer is encouraged. If you have a question concerning a particular comment, contact your LANTNAVFACENGCOM reviewer. This may avoid unnecessary re-submittal of plans and specifications due to a misunderstood comment. The reviewer’s name, phone number and email address can be found on the comment sheets.

• Mechanical Engineering Design Requirements

• Energy Computations

New facilities and facilities undergoing major renovation are required to be analyzed to determine the most cost effective and practical fuel source(s) and heating and cooling types.

• Definitions

Major Renovation

Major renovation is defined as change in the functional use of the building, reconfiguration of interior partitions and reallocation of spaces, changes in the features of the building envelope and replacement of lighting, HVAC and water heating systems. Unless programmed and funded to upgrade the facility to new building energy conservation levels, major renovation projects are exempt from compliance with Design Energy Budgets, Active Solar Analysis and Special Studies requirements stated hereafter. All building components and systems being renovated or replaced shall comply with their respective energy conservation criteria and be evaluated using economic criteria provided in the National Bureau of Standards Handbook 135 (reference a).

Minor Repair and/or Replacement

Minor repair and/or replacement of windows, doors, lighting fixtures, HVAC equipment and water heating equipment in existing systems shall comply with the energy conservation criteria only to the extent of the items being replaced. Other portions of the existing system(s) not affected by these replacements are exempt from these criteria.

Fuel sources that are available in the vicinity of the facility, or are practical candidates to be delivered to the facility shall be considered. Utilize the fuel conversion factors provided by Table 1.

Table 1

Fuel Conversion Factors

Type of Fuel	Conversion Factors (see note (a))	Notes
Anthracite Coal	28.4 Million Btu/Short Ton	
	29.9 kJ/kg	
Bituminous Coal	24.6 Million Btu/Short Ton	
	25.9 kJ/kg	
Electricity	3413 Btu/KWH	see note (b)
	12.3 MJ	
No. 2 Distillate Fuel Oil	138,700 Btu/Gallon	
	38.7 MJ/L	
Residual Fuel Oil	149,700 Btu/Gallon	
	41.8 MJ/L	
Kerosene	135,000 Btu/Gallon	
	37.7 MJ/L	
LP Gas	95,500 Btu/Gallon	
	26.6 MJ/L	
Natural Gas	1,031 Btu/Cubic Foot	
	38.5 MJ/L	
Purchased or	1,000 Btu/Pound	see note (c)
Steam from Central Plant	2.3 MJ/kg	

Notes:

(a) At specific installations where the energy source Btu content is known to vary consistently by 10% or more from the values given below, the local value may be used provided there is adequate data on file for two years or more to justify the revision and that this value is expected to hold true for at least five years following building occupancy.

(b) When 10% of more of a building's annual heating consumption will be derived from electric resistance heating, the electric resistance portion shall be multiplied by a factor of 2.2 to reflect additional conversion losses.

(c) High temperature, medium temperature, or chilled water from a central plant shall use the heat value of fluid based on the actual temperature and pressure delivered to the 5 ft (1.5 m) line.

Building heating and cooling systems shall also be analyzed to determine the most cost effective system types. In addition, all facilities are required to meet the minimum requirements of ASHRAE/IESNA Standard 90.1 or the U.S. Energy Star Housing Program Requirements (for low-rise housing projects) as applicable. Documentation of compliance must be kept and submitted as part of the project records. The following are components of the energy computation process.

- **Energy Analysis Form E-1:**

  The building heating and/or cooling fuel source and system design alternatives for energy and life cycle analysis must receive pre-approval from LANTNAVFACENGCOM by submitting Form E-1. Form E-1 may be reproduced from the Mechanical Engineering Design Guide at http://www.lantdiv.navfac.navy.mil/pls/lantdiv/url/page/CI4_ENGINEERING_AND_DESIGN (Click on Guidance and Policy Tab). The Form E-1 submittal shall include a description of each fuel source and system type to be analyzed and a building floor plan with zones and equipment areas indicated.

- **Energy Analysis:**

  New DoD criteria have been adapted which revises the energy conservation and energy computations required. The old DoD Design Energy Target system is no longer applicable. All new facilities and major renovation projects shall now conform to ASHRAE/IESNA Standard 90.1-1999, plus all amendments made to the Standard up to the date of the A/E contract. Note that compliance with this Standard imposes Architectural, Mechanical, and Electrical requirements on the design of the facility. Provide documentation to support compliance with this Standard, including a narrative describing the method of compliance, descriptions of building systems and components to be incorporated, and computer analysis discussion, input and output.

- **Life Cycle Cost Analysis (LCCA):**

  To select from the alternative sources and systems indicated on Form E-1, perform a life cycle cost analysis, which compares the present worth of first cost, operating cost, maintenance cost and replacement cost of each alternative. Operating costs shall be developed using a nationally recognized, hour-by-hour, computerized energy simulation program, such as "DOE-2" or "Energy Plus". LCCA calculations shall be on a 25-year basis. LCCA calculations shall be performed using the latest version of the Building Life Cycle Cost (BLCC) computer program. BLCC is a National Institute of Standards and Technology (NIST) computer program providing computational support for the analysis of capital investments in buildings. BLCC is available for download at http://www.eren.doe.gov/femp/techassist/life_cycle_cost.html. If based on the size and/or simplicity of the facility, it does not seem appropriate to perform a Life Cycle Cost Analysis, contact the LANTNAVFACENGCOM Mechanical Design Branch.

- **Energy Star:**

  Per Executive Order 13123 dated 3 June 1999, "Agencies shall select, where life cycle cost effective, Energy Star and other energy efficient products when acquiring energy using products. For product groups where Energy Star labels are not yet available, agencies shall select products that are in the upper 25% of energy efficiency as designated by FEMP" (Federal Energy Management Program). The Energy Star and FEMP programs cover residential, light commercial and heavy commercial HVAC equipment, appliances, construction materials, lighting technologies, office equipment and water saving fixtures. To comply with this order, insure that all HVAC equipment, appliances, and other electrical equipment conform to the minimum efficiencies listed by Energy Star and FEMP. The FEMP web site lists all Energy Star and FEMP rated products and provides recommended efficiencies and life cycle data. The FEMP web site is http://www.eren.doe.gov/femp/procurement.

• LANTNAVFACENGCOM Mechanical Branch Design Policy

The following plumbing and mechanical policy statements are intended to address requirements for geographic areas throughout the LANTNAVFACENGCOM jurisdiction. Modification to policy is permissible only if overruled by local or governing code or Activity Design Criteria. Activity Design Criteria is available for download at http://www.lantdiv.navfac.navy.mil/pls/lantdiv/url/page/CI4_ENGINEERING_AND_DESIGN (Click on Guidance and Policy Tab).

- **Plumbing**

  Access Panels - Provide access panels in floors, walls, and ceilings (except in lay-in tile applications) as required to access isolation valves, tempering valves, water hammer arrestors, etc. Indicate location and size on drawings. Verify that the dimensions will yield reasonable accessibility.

  Backflow Preventers – The enforcing documents for backflow prevention are the Safe Drinking Water Act, CFR 40 Chapter 141 and 142 and OPNAV Instruction 5090.1B. These documents require programs to be in place to ensure safe drinking water. However, localities have final authority and local codes can differ considerably. Generally, every piece of equipment (i.e. boiler, ice maker, water fountain…) requires individual protection by a dedicated backflow preventer. In addition, many hazardous type buildings, such as hospitals, industrial buildings, etc., require a reduced pressure backflow preventer in the water main to the building.

  Domestic Water Heaters - Indicate the minimum prescribed "Energy Factor" of 0.92 (as prescribed by FEMP) in the equipment schedule for residential electric and gas domestic hot water heaters.

  Domestic Hot Water Storage Temperature – The Environmental Health Committee (EHC) has recommended to the pertinent ASHRAE Technical Council that domestic water heaters be set at 131 deg F (55 deg C) instead of the long standing HUD recommendation of 120 deg F (48.9 deg C) for the control of legionella disease (legionellosis). Where warranted, consider the use of a tempering valve to prevent scalding.

  Emergency Shower and Eyewash Stations – Guidance can be found in the "Interim Technical Guidance" directory at http://www.lantdiv.navfac.navy.mil/pls/lantdiv/url/page/CI4_ENGINEERING_AND_DESIGN (Click on Guidance and Policy Tab).

  Floor Drains - Provide drains for coil condensate, relief valve discharges, etc. Coordinate placement on the mechanical and plumbing drawings.

  Pipe Settlement - Check the potential for under floor pipe settlement. Where the potential exists, support pipe from floor slab. Support pipe from floor slabs in structures with pile foundations.

  Room Names and Numbers – Show room names and numbers on all plumbing plans.

  Tempering Valves - Utilize tempering valves where the potential for scalding exists.

  Water Hammer Arrestors - Provide water hammer arrestors at all quick closing valves and where considered necessary. Indicate size and location on drawings. Provide access to all water hammer arrestors.

- **Mechanical**

Access Panels - Provide access panels in floors, walls, and ceilings (except in lay-in tile applications) as required to access valves, dampers, fire dampers, duct coils, filters, equipment, etc. Indicate location and size on drawings. Verify that the dimensions will yield reasonable accessibility.

Air Vents - Show location of automatic and manual air vents required in piping systems. Provide manual type vents where possible. Pipe the drains from automatic vents away from concealed areas for visual inspection and to prevent damage to ceilings, etc. Use of automatic air vents is discouraged and should be minimized.

Anchors for Piping - Show anchor locations on plans. Provide anchor detail(s).

Balancing Dampers – Provide opposed blade manual balancing dampers for both the minimum and the maximum outside air ducts where automatic min/max outside air dampers are required. Indicate opposed blade manual balancing dampers for both the main and return duct and the main relief duct on all return air fans; dampers shall be in close proximity to the automatic return and relief dampers. Provide manual volume dampers for all main and branch ducts; these should include all supply, return, and exhaust ducts. Do not use splitter dampers for air balancing; splitter dampers are not endorsed by SMACNA for balancing applications. All dampers and their intended locations shall be clearly delineated on the floor plans.

Barometric Dampers – Provide barometric dampers for all boilers requiring negative draft.

Balancing Valves and Cocks – Provide as required for hydronic balance. The designer shall specify the size of the balancing valves required in each application, cognizant of the required differential pressure requirements in the pipe systems; do not assume line size valves as appropriate for the application. A balancing device is required in coil bypasses only when coil drops are in excess of 2 feet w.g. (6 kPa).

Boiler Foundations – Provide detail.

Boiler Procurement – DoD policy requires that boilers procured be ASME certified. Approval and installation of non-ASME boilers is in violation with current Air Force Instruction (AFI 32-1068) and Navy Instruction (NAVFACENGCOMINST 11310.6). This policy is mandatory and non-negotiable. Non-ASME certified boilers are not an acceptable option for boilers installed on any DoD facility either within, or outside, the United States.

Clearances – Ensure that all equipment will fit allotted space with manufacturers recommendations for service and maintenance space adopted. Indicate filter and tube or coil pull areas for all equipment. Verify adequate door dimensions to permit passage of equipment into mechanical spaces.

Check Valves – Provide as required to prevent backflow and at the discharge of most pumps. When used in drain lines, verify sufficient head to open flap to regain flow. Provide non-slam type on high head applications. Provide damping type on air compressor discharges.

Chemical Feeders – Provide a detail of a chemical shot feeder. Fill openings should be no higher than 5 feet (1.5 meters) above the finish floor for ease of filling.

Chilled Water Systems – Chiller manufacturers recommend minimum system volumes for stable operation and accurate control. In small systems it may be necessary to install an inertia tank in the chilled water loop to achieve the required minimum system volume.

Check the requirements of the chiller manufacturer and provide the inertia tank of sufficient volume when required.

Chillers – When multiple chillers serve a common central chilled water system, install a flow control balancing valve (circuit setter) on the leaving side of the chilled water and condenser water (where applicable) of each chiller. Flow orifices with butterfly valves should be provided for larger pipe sizes.

Condensing Boilers – Hydronic systems with condensing gas-fired boilers should be checked to see if the system has sufficient water volume. The rule-of-thumb is the system should contain a minimum volume equal to five (5) minutes of water flow through the system pump. This insures there is sufficient water volume to prevent short cycling of the burner. If there is insufficient water volume, an inertia tank should be installed to attain the minimum system volume required. Non-condensing boilers do not require this minimum.

Condensing Temperatures – Indicate the design condensing temperature for air-cooled condensers, chillers, etc as ambient design temperature plus 5° F (2.8° C) dry bulb.

Cold Water Make-up – Show the make-up to each closed water system. Show all accessories, to include pressure reducing valves (PRV), relief valves, and backflow preventers. Show pressure reducing and relief valve pressure settings. Provide pressure gauges up and downstream of the PRV. Provide hose bibbs in the make-up water line to cooling towers and evaporator condensers for washdown of equipment.

Combustion Air – Provide combustion air for gas and oil-fired equipment in accordance with NFPA requirements.

Conflicts – Check for conflicts. Most common are: electric lights and diffusers; electric duplex outlets and fin radiation; rain leaders or soil stacks and ductwork; bond beams or joists and ducts, etc.

Control Dampers – There are two types of control dampers in general use, the parallel blade type and the opposed blade type. Parallel blade dampers are good for two-position, on/off control, where they should be sized for minimum pressure drop. However, because a large portion of their stroke is given up to just diverting the airflow and not throttling it, they are not well suited for modulating control. When they are used to modulate airflow, their pressure drop should be between 20% and 100% of the total system pressure drop. Opposed blade dampers are preferred for modulating applications, but for best performance, their pressure drop should be between 5% and 20% of the total system pressure drop. They are effective for two-position, on/off applications as well, but are more expensive than parallel dampers.

Control Diagrams – Provide for all large or complicated projects. Show controller functions, such as N.O., N.C., C., etc. Indicate all set points. See NFGS 15910 for detailed information regarding presentation.

Control Valves – Indicate flow rates, minimum Cv or maximum pressure drop, nominal valve size, service (i.e. steam, hot water, etc), configuration (i.e. 2-way or 3-way), and action (i.e. modulating or 2-position). Consider use of a “Control Valve Schedule”. See the discussion under “Metric Valve Coefficient”.

Cooling Towers – Verify that for all cooling towers that are specified to have a condenser water by-pass for regulation the condenser water supply temperature, that a butterfly valve is specified to be installed in the by-pass line.

Door Louvers – Size, show location or coordinate with architectural drawings.

Draft Hoods – Provide for each gas-fired piece of equipment.

Drain Lines – Show drain lines from air handling units, fan coil units, etc. Provide a water seal on drains as required. Terminate condensate drain lines with a downturn into a floor sink.

Drain Valves – Provide drain valves at all low points in piping systems.

Duct Leakage and Testing – Indicate those HVAC duct systems to be leak tested on the contract drawings. All new duct systems shall be leak tested, unless the requirement is waived by the LANTDIV Mechanical Branch. Specify the test type and test pressure for each duct system (supply air, return air, exhaust air, and outside air ductwork) subject to testing. See "Duct Construction Classifications".

Duct Lining – Indicate acoustical duct lining where required on the drawings. Increase the duct dimensions as required.

Duct Construction Classifications – Indicate duct static pressure, seal and leakage classifications on the drawings. Refer to SMACNA-HVAC Air Duct Leakage Test Manual, 1st Edition, 1985.

Duct Sealing Requirements – Require Seal Class "B" on all new duct systems, as a minimum.

Electric Rooms – No pipes (pressure or gravity) shall be installed within, or pass through, electrical or communication rooms.

Equipment Room Ventilation – Provide for combustion air to all gas and oil-fired boilers and furnaces. Ventilate such equipment rooms with a thermostatically controlled supply fan.

Equipment Supports – Show hanger rods and structural supports for all ceiling or roof-mounted air handling units, heating/ventilating units, fan coil units, exhaust or supply fans, expansion tanks, etc. Provide for vibration isolation where required and schedule the vibration isolation components on the drawings.

Equipment Service Space – Indicate pull areas for coils, tube and filters in all major equipment, including air handling units, chillers, converters, etc. Provide access panels as required.

Exhaust/Intake Locations – Provide adequate separation between outside air intakes and exhaust outlets, waste vents and boiler stacks. Consider prevailing winds and force protection requirements. Outside air intakes must be 3.0 m (10 ft) minimum above finish grade to satisfy Anti-Terrorism Force Protection (ATFP) requirements.

Expansion Loops and Devices – Provide expansion devices as required. Detail and dimension loops and schedule joints indicating minimum total traverse and installed expansion traverse. Indicate guide spacing. Avoid the use of expansion joints where possible due to the high resultant thrust. Instead utilize geometry and ball joints where possible.

Fan Coil Units – Schedule cooling capacity based on high-speed fan operation. Install auxiliary drain pans under fan coil units located above ceilings.

Fire Dampers – Show fire dampers and access panels in ductwork penetrating fire rated walls and floors. See NFPA 90A.

Fire Station Diesel Exhaust – Provide an engineered fire apparatus exhaust removal system. The system should include an overhead sliding track mechanism to permit a flexible exhaust hose to travel with the fire apparatus into and out of the apparatus bays. The fire apparatus exhaust hose shall automatically disconnect from the vehicle as it exits the bay. Competitive manufacturers of such exhaust systems include Nederman and PlymoVent. Additional design guidance can be found in the "Interim Technical Guidance" directory at http://www.lantdiv.navfac.navy.mil/pls/lantdiv/url/page/CI4_ENGINEERING_AND_DESIGN (Click on Guidance and Policy Tab).

Flexible Connections – Provide flexible connections in ductwork at equipment. Support duct at flexible connections to ensure proper alignment.

Flexible Duct – Verify that flexible duct lengths shown on the drawings do not exceed the maximum length specified; normally 5 feet (1524 mm).

Flow and Slope Arrows – Indicate the flow direction of pipe on the drawings. Show slope direction and rate of slope on gravity piping systems.

Flow Control Balancing Valves – Provide flow control balancing valves in the discharges of all closed circuit pumps and at all hydronic terminals. For pipe sizes larger than 3 inches (80 mm), a flow orifice combined with a butterfly valve should be specified. Detail installation of all flow control balancing valves in accordance with the manufacturer's recommendations regarding the minimum straight lengths of pipe up and downstream of the device. Designers should select the proper size flow control-balancing valve for each application to ensure the devices are not oversized; contract drawings should specify the valve size for each application. Oversized flow control balancing valves yield inaccurate flow readings.

Freeze Protection – Design pipe temperature maintenance systems (i.e. heat trace) to the lowest recorded temperature in the Joint Services Manual, TM 5-785, NAVFAC P-89, AFM 88-29, "Engineering Weather Data", July 1978 for the pertinent geographic area.

Fouling Factors – Indicate fouling factors for all water-to-air and water-to-water heat exchangers (i.e. coils, converters, chillers, etc). Indicate in the appropriate equipment schedule. Fouling factors shall be accompanied with their appropriate English or SI units.

Ground Coupled Heat Pumps – See "Ground-Coupled Heat Pump (GCHP) System Design Guidance" located in this document.

Guides for Piping – Show pipe guide locations on all aboveground anchored piping.

Humidistat – Show locations on drawings, when required.

Infra-Red Gas Radiant Heaters – When using non-condensing gas infra-red heaters, the length of the exhaust flue should be minimized. To minimize condensation, run the flue horizontally with a slight pitch down from the heater to a sidewall exit. Heaters should be properly braced where excessive movement, such as by wind through an open hangar bay door, may cause separation of radiant pipe sections and rupture of gas connections.

Legionella Disease – Background information regarding this topic can be found at http://www.lantdiv.navfac.navy.mil/pls/lantdiv/url/page/CI4_ENGINEERING_AND_DESIGN (Click on Guidance and Policy Tab).

Louvers – Provide rain or storm proof louvers at wall intakes and exhausts. Indicate dimensions, airflow rate, and air pressure drop. Consider the potential for carry-over of wind driven rain.

Metric Valve Coefficient – One of the "casualties" of metrification is the standard valve coefficient, Cv, which is defined as the quantity of water that flows through a valve (in GPM) when the differential pressure across the valve is maintained at 1 psi. In North America, the metric version of the valve coefficient is Kv, which can be calculated from the flow of water in cubic meters per hour at a pressure drop of 100 kPa, or it can be calculated in cubic meters per second at 1 kPa pressure drop. Obviously, each of these methods yields a different number. In conclusion, do not use Cv on a metric project, and to avoid confusion, always note dimensions on which the coefficient is based.

Motor Starters – Indicate motor starter NEMA sizes in the mechanical equipment schedules.

Outside Air Ducts – Size outside air ducts for velocities no lower than 800 fpm (4.1 m/s) for accurate flow measurement. Provide a straight duct of suitable length to facilitate traversing.

Pressure Gauges – Indicate pressure gauge ranges; system operating pressures should be midrange on the graduated scale.

Roof Fans – Details of roof exhaust fans shall include a requirement for airtight seals between the fan frame and the wood nailer of the roof curb. The details shall require the duct of ducted exhaust fans to extend up through the fan curb to a flanged and sealed termination at the top of the curb.

Room Names and Numbers – Show room names and numbers on all mechanical plans.

Screens – Provide insect or bird screens, as applicable, at all building intakes and exhausts.

Seismic – Pipe and duct supports shall comply with the requirements of the latest edition of SMACNA "SEISMIC RESTRAINT MANUAL, Guidelines for Mechanical Systems". The designer shall indicate the "Seismic Hazard Level" (SHL) on the contract drawings. All pertinent seismic detailing shall be presented on the contract drawings. Additional guidance can be found at http://www.lantdiv.navfac.navy.mil/pls/lantdiv/url/page/CI4_ENGINEERING_AND_DESIGN (Click on Guidance and Policy Tab)

Steam Boilers – On boiler start-up, the condensate in a gravity system may not return quick enough to maintain the boiler water level. Contact the boiler manufacturer for tank size and location.

Tanks (Expansion and Compression) – Use diaphragm type expansion tanks. Size the expansion tank according to the latest edition of the ASHRAE Systems Handbook. Indicate the acceptance volume, nominal dimensions, configuration (i.e. horizontal or vertical) and precharge air pressure.

Thermostats – Show thermostat locations on the plans. Identify heating, cooling, heating/cooling and ventilation thermostats.

Thermometers – Indicate thermometer temperature ranges; system operating temperature should be midrange on the graduated scale.

VAV – See "Variable Air Volume (VAV) HVAC System Design Guidance" located in this document.

Vibration and Noise Isolation – Where vibration and/or noise isolation is required, provide a vibration isolator schedule on the drawings indicating type of isolator, application, and deflection in inches (mm).

- ## Variable Air Volume (VAV) HVAC System Design Guidance

This guidance is intended for use by qualified engineers who are responsible for the preparation and review of plans and specifications for the installation of VAV systems. The recommendations that follow are intended to complement the guidance and requirements of ASHRAE and various NAVFAC and DoD Manuals.

- **VAV Design Recommendations:**

Do not oversize the system. Do not add safety factors in the load calculations. Safety factors not only have the ramification of added cost, but also penalize the system during frequent part load conditions commonly experienced in humid, coastal locations.

Use computerized load calculations based on the ASHRAE Transfer Function Method.

Select all central air handling equipment and central plant equipment for "block" loads. Spread diversity through the supply ducts, taking full diversity at the air handling unit, and lessening diversity when moving away from the air handling unit toward the VAV terminal units, until no diversity is taken at the distant VAV terminal run outs.

Design for both peak and part load conditions.

Address the psychrometric performance of the cooling coils, with full consideration of the method of capacity control and its limitations, during part load conditions when the sensible heat ratio can be significantly reduced. Submit part load design calculations.

Check the fan operating characteristics throughout the range from the minimum to the maximum flow conditions that will be experienced. Evaluate the off-peak turndown requirements for the main air handler VAV fan. All forms of airflow output control, including variable frequency drives, vortex inlet vanes and discharge dampers, have minimum turndown capabilities. Do not use discharge dampers or inlet vanes for fan modulation. Variable frequency drives are the preferred methods for air volume modulation.

Design a positive means of maintaining ventilation rates during part load conditions. Select the minimum primary air requirements of the VAV terminal units to maintain at least the minimum outside air ventilation requirements. When using airflow measuring stations (AFMS) for monitoring or maintaining constant outside air ventilation rates, avoid placement of the AFMS in the outside air duct unless a minimum of 12 duct diameters of straight duct downstream of the outside air louver can be provided. Turbulence generated by the outside air intake louver will generate high turbulence and a highly unstable control loop. An alternate and preferred method to maintain a constant outside air ventilation rate uses an air injection fan or a constant air volume (CAV) terminal with a pressure independent velocity controller in the outdoor air intake to keep outdoor airflow constant as the VAV air handler fan modulates. Provide a low velocity filter module upstream of the air injection fan to prevent dust/dirt build up that may clog the pitot tubes associated with the volume regulator. Provide a duct access door at the inlet to the CAV terminal box for periodic inspection and cleaning.

Use the static regain method in design of the supply ductwork. Design return ductwork using the equal friction method.

Provide control for a constant cooling supply air temperature. Resetting the supply air temperature upwards increases the coil sensible heat ratio and results in elevated space relative humidity.

Use DDC controls; pneumatic controls present problems with repeatability and maintenance.

Locate the static pressure sensor for modulating fan capacity two-thirds to three-quarters the distance from the supply fan to the end of the main trunk duct.

Provide protection against over pressurization of the supply duct system.

Use pressure independent (PI) terminal units. Use of PI units compensate for pressure fluctuations in the duct system, thus enhancing control stability.

Avoid use of light troffer return units. Light troffers reduce room sensible loads with undesirable effects on room air changes and outdoor ventilation distribution.

Consider the method of controlling cooling coil capacity, especially in the more humid climates. VAV is inherently one of the best of the chilled water systems for air conditioning in tropical climates. With many of the other type chilled water based systems, the coil sensible heat ratio increases with reduced cooling load, with drastic effects on room relative humidity. In VAV systems, however, the coil sensible heat ratio remains nearly constant as it unloads, even with a chilled water valve throttling for a constant supply air temperature.

Provide sufficient steps of unloading in DX VAV systems. A reduced number of unloading steps result in larger jumps in supply air temperature, resulting in system instability. DX VAV applications are restricted to the use of packaged air handlers; built-up DX VAV air handlers are prohibited.

Use round ducts wherever space availability permits. Round ducts are acoustically superior to rectangular ducts and usually cost less. In high velocity systems, the additional friction losses of duct walls and balancing dampers of rectangular ducts cause the system to be inherently less stable.

Proper VAV box primary air entry conditions are critical for achieving stable, accurate airflow delivery. Every effort must be made to avoid high turbulence in the proximity of the VAV terminal flow sensor. Design the primary air duct branches to the VAV terminals with a straight duct section of at least 6 to 8 duct diameters (more if required by specific manufacturers). Reducer and increaser duct fittings installed immediately upstream of the VAV terminal connection collars are prohibited. If the branch duct size is other than the VAV terminal connection collar size, install the reducer or increaser fitting upstream of the aforementioned straight duct section.

Primary air connections to VAV terminals should always be with a rigid duct. If a section of flexible duct, or a flexible connection, is required for vibration control, limit the length to no more than 12 inches (305 mm), and ensure that it is placed at least 6 to 8 duct diameters upstream of the VAV box collar connection/flow sensor.

VAV terminal boxes have minimum primary air velocity limitations imposed by the volume regulators utilized. Though many manufacturers claim their VAV boxes can deliver minimum primary air at flow rates resulting in inlet velocities of 400 fpm (189 L/s) and a velocity pressures of 0.01 inch w.g. (2.48 Pa), the lack of a certifying agency to test the manufacturer's claims support a more conservative approach. Minimum primary airflow rates shall be established to attain minimum velocity pressures of no less than 0.03-inch w.g. (7.45 Pa).

Special consideration must be given when fan-powered VAV boxes are specified and when it is necessary to specify a VAV box fan CFM in excess of the specified maximum primary air CFM. When used with a dropped ceiling return plenum, the excess VAV box CFM will introduce secondary air into the conditioned space. This has the effect of transferring return side coil cooling loads to room-side sensible loads. Always make sure the transferred sensible heat is taken into account in the calculated room-side sensible heat. Failure to do so may result in inadequate primary airflow rates to satisfy the room sensible heat loads.

Discharge dampers shall be installed on all series fan-powered VAV boxes (SFPVAV), regardless of the type of fan speed control utilized (3-speed fan switch or solid state speed control). The problem with using the solid speed controller to achieve air balance is that most fans have more static than the product catalog indicates. If discharge dampers are not provided, then speed controllers must be turned to near minimum positions to achieve air balance. Sometimes the setting is so low the fans will not start, causing controller burn out. The ideal scenario is to first balance the SFPVAV with the discharge damper, then trim with the speed controller. The utilization of a discharge damper has the added benefit of abating noise.

When it is necessary to install VAV terminals at high elevations above finished floors, service and maintenance accessibility must be carefully analyzed. Where mounting heights are in excess of 12 feet (3.6 m) above finished floors, special accommodations may be necessary:

1. Avoid using fan-powered VAV boxes in such locations, since there are many serviceable components involved. Instead, consider using non fan-powered terminal boxes for use in high mounting height locations to eliminate the need for fan servicing and filter change access.

2. When DDC controls are installed, specify the installation of the DDC digital controller remotely mounted at an elevation above the finished floor to facilitate ease of access.

3. If scaffolding, scissor lifts, ladders or other means is required to access VAV units, special considerations must be made. Be sure clear floor area is available below the VAV boxes to facilitate the means of access (i.e. scaffolding, etc) and in an area that will be likely to remain clear of permanent or semi-permanent equipment or furnishings.

4. When DDC controls are provided for VAV boxes, specify the ability to monitor VAV box hot water control valve position (if provided with hot water coils), control damper position, primary airflow, flow sensor pressure differential, and box leaving supply air temperature. The means to monitor VAV box function will maximize the means to troubleshoot remotely, thus reducing the frequency for above ceiling access by maintenance personnel.

5. Do not use pneumatic or electronic controls for VAV boxes mounted in high areas.

6. Specify the integral mounting of communication ports for the VAV box digital controllers to the room zone temperature sensor. When occupied/unoccupied modes of control are required of the VAV system, specify remote momentary override

switched mounted integral to the room zone temperature sensors to permit non-standard schedule operation during unoccupied modes.

Fan-powered VAV terminal boxes can be noisy. Perform an acoustic analysis to ensure designs are within acceptable NC criteria noise levels. Pay particular attention to noise attenuation in locations where the boxes are installed in spaces without dropped ceilings.

Analyze potential for sound breakout from main supply air ducts. Provide attenuation as required.

Avoid economizers, unless significant benefits can be shown. Economizers can save a lot of energy if properly maintained, even so it always adds control complexity and makes the entire system less stable. If economizers are used, observe the following:

1. Use dry bulb sensing, rather than enthalpy controls.

2. Return fans often cause problems. Without an economizer, return fans are not necessary. When integral to an economizer system, however, they must energize whenever the supply fan does, whether in economizer mode or not. Matched capacity modulation of the return and supply fan can be problematic with resultant building pressurization problems. As an alternate, try to design the system with barometric relief to eliminate the need for a return fan. If barometric relief is not feasible, consider a relief fan in lieu of a return fan. Relief fans energize only during the economizer cycle and are easier to control.

• Ground-Coupled Heat Pump (GCHP) System Design Guidance

This guidance is intended for use by qualified engineers who are responsible for the preparation and review of plans and specifications for the installation of GCHP systems. The recommendations that follow are intended to complement the guidance and requirements of ASHRAE and recognized consortiums, such as the International Ground Source Heat Pump Association (IGSHPA), telephone 1-800-626-4747, website address: http://www.igshpa.okstate.edu/; the Geothermal Heat Pump Consortium, 1-888-ALL-4-GEO, website address: http://www.ghpc.org; the Geo-Heat Center, funded by DoE and located at the Oregon Institute of Technology, telephone 1-541-885-1750, website address: http://www.oit.edu/~geoheat. At this time no DoD guidance exists on the design of GCHP systems.

- **GCHP Design Recommendations:**

Nonresidential, commercial scale ground source heat pump systems require the use of computer design software. Such software should consider the interaction with adjacent loops and long-term buildup of rejected heat in the soil. Sources of suitable PC based software include:

1. GCHPCalc Version 4.0, Energy Information Services, P.O. Box 861462, Tuscaloosa, AL, 35486-0013, web address: http://www.geokiss.com, email: geokiss@home.com.
2. GLHEPRO Version 3.0, International Ground Source Heat Pump Association (IGSHPA), telephone: 1-800-626-4747, web address: http://www.igshpa.okstate.edu/Publications/catalog/1998/Software.html
3. GS2000 Version 2.0, Caneta Research Inc., 7145 West Credit Drive Suite 102, Building 2, Mississauga, Ontario L5N 6J71-905-542-2890, email: caneta@compuserve.com.

Provide a bypass line around the condenser of each heat pump unit to facilitate flushing and purging the condenser loop without subjecting the condenser coil to residual construction debris.

Provide isolation valves and valved tee connections for flushing and purging of the well field independently from the building condenser water system.

Do not provide automatic water makeup in residential GCHP systems. Reserve the added complexity and cost to larger, non-residential systems of 10 tons or larger.

Utilize cupronickel refrigerant-to-water heat exchangers in open condenser loops only. Closed loop geothermal condenser loops should not require the added corrosion protection afforded by cupronickel.

Provide test ports (sometimes referred to as "Pete's plugs") on the inlet and outlet to each heat pump unit, circulating pump and desuperheater, if incorporated.

Utilize reverse return headers in large well fields. For heat pumps with reduced flow requirements of 2 GPM/ton or less, series return should be considered in order to maintain fluid velocities necessary to foster good heat transfer. The decision to commit to reverse return should be based on installed cost, pumping costs and the system flow requirements by avoiding laminar flow, which inhibits fluid side heat transfer. Consult ASHRAE and IGSHPA Design documentation for additional information.

Regulatory requirements for vertical wells vary widely among States. Some regulations require partial or full grouting of the borehole. The State of Virginia, for example, requires bentonite or cement grout seals in the top 20 feet (6.1 meters) of a borehole, while in North Carolina, the State requires a full depth seal. A full depth bentonite seal, however, is not necessary; the wells in N.C. may be grouted with cement mixed with soil for the bore drilling. Consult current state and federal regulations, as well as relevant building codes.

The thermal conductivity of grouting materials is typically low when compared to the conductivity of native soils. Grout acts as an insulator and will, thus, hinder heat transfer to the well field. When governing regulations permit, there are alternatives that should be considered:

1. Reduce the quantity of grout to an absolute minimum. Fine sand may be used as backfill where permitted, but caution must be exercised to ensure the interstitial space between pipe and borehole is filled to enhance conductivity.
2. Use thermally enhanced grout. Consult ASHRAE, "Commercial/Institutional Ground-Source Heat Pump Engineering Manual", and Spilker, Elliott H. (January 1998), "Ground-Coupled Heat Pump Loop Design Using Thermal Conductibility Testing and the Effect of Different Backfill Materials on Vertical Bore Length", Proceeding of ASHRAE, January 1998 meeting, San Francisco, VA, paper SF98-1-3.
3. Reduce the borehole diameter as much as possible to reduce the insulating effects of grout or backfill.

In geographic areas with heating dominated climates, an antifreeze solution may be required if condenser loop temperatures are expected to drop below 41° F (5° C). Avoid use of antifreeze, but if necessary, keep concentrations to a minimum.

Use condenser water circulating pumps with high efficiency motors. Design them to operate near their peak of maximum efficiency.

- # Pre-Design Services

  - ## Field Investigation

  - ## Energy Studies

    The A&E shall satisfy the energy conservation requirements outlined under paragraph entitled “Energy Computations”. Integral to this process is the timely submission of the Energy Analysis Form (Form E-1) to LANTNAVFACENGCOM.

    - **Solar Analysis**

      When required by the “Appendix A”, the economic feasibility of incorporating an active solar domestic water preheating system will be evaluated by LANTNAVFACENGCOM with building information provided by the A&E via submission of the Solar Analysis Form (Form S-1) at the 15% project stage.

    - **Energy Analysis**

      The number and type of alternatives to be analyzed shall be based on project information provided in the scope of work. The Energy Analysis Form (Form E-1) shall indicate the proposed alternatives and zones and shall be accompanied with the best available floor plan clearly depicting the zones. Upon submission to LANTNAVFACENGCOM by the A&E at the 15% project stage, the Mechanical Engineering Branch (Code CI43) will review the recommendations and return the form to the A&E: “Approved”, “Approved as Noted” or “Disapproved”. Contact the Mechanical Engineering Branch prior to submitting Form E-1, if you have any questions.

  - ## Computerized Energy Analysis

    After receiving the approved forms from LANTNAVFACENGCOM, the A&E shall perform a computerized energy analysis and a life cycle cost analysis for any building or major renovation that is heated only or heated and air-conditioned, or air-conditioned that exceeds 3000 ft^2 (279 sm) of gross floor area.

    - **Energy Analysis Programs**

      The energy analysis program shall be a professionally recognized and proven computer program which makes hourly calculations. For additional information, consult paragraph entitled “Energy Computations”.

    - **Life Cycle Analysis Program**

      The life cycle analysis shall be performed using the latest version of the Building Life Cycle Cost (BLCC) computer program developed by the National Institute of Standards and Technology (NIST). For additional information, consult paragraph entitled “Energy Computations”.

- # Design Services

- ## Plumbing Basis of Design

Address the following:

Design Criteria - Identify the governing codes and criteria, including federal and military handbooks, utilized for the design. Include the titles and the date of the latest edition or publication. References to codes and criteria should be made in the narratives of the Basis of Design.

Estimated Water Demand **-** Estimate the water demand in gpm (L/s) based on the type and number of fixtures required for each building.

Water Pressure **-** Indicate the minimum and maximum water pressure in psi (kPa) at each building. Indicate if booster pumping will be required.

Domestic Hot Water **-** Indicate the type, size and design water temperature of the domestic water heater and the distribution system. Indicate the extent of domestic hot water recirculation within the building. If shown economically feasible by life cycle cost analysis, state whether heat recovery will be utilized.

Special Mechanical Systems **-** Provide a description of special mechanical systems such as compressed air, hydraulic, nitrogen, lubrication oil, etc.

Backflow Prevention **-** Identify the systems and fixtures requiring backflow preventers.

- ## Mechanical Basis of Design

Address the following:

Design Criteria - Identify the governing codes and criteria, including federal and military handbooks, being utilized for the design. Include the titles and the date of the latest edition or publication. References to codes and criteria should be made in the narratives of the “Basis of Design”.

Design Conditions **–** Provide a tabulation of the design indoor and outdoor heating and cooling conditions for all occupied and unoccupied areas.

1. Outside Design Temperatures – Utilize the Joint Services Manual, TM 5-785, NAVFAC P-89, AFM 88-29, “Engineering Weather Data”, dated July 1978. Use 2-1/2% dry bulb temperature and 5% wet bulb temperature for summer and 97-1/2% for winter in the design of all new and renovation type construction, except for applications where specialized technical requirements demand exact temperature and/or humidity control. For these areas, use 1% dry bulb temperature and 1% mean coincident wet bulb temperature for summer and 99% dry bulb for winter.

2. Heating Indoor Design Conditions – Heating indoor design temperature for personnel comfort should be 68°F (20°C) for administrative and living areas, 55°F (12.8°C) for working areas, and 40°F (4.4°C) for storage areas and for the prevention of freezing.

3. Cooling Indoor Design Conditions – Cooling indoor design temperature for personnel comfort should be 15°F (9.4°C) less than the 2-1/2% outdoor dry bulb weather condition, but should not exceed 78°F (25.6°C) dry bulb or be less than 75°F (23.9°C) dry bulb. The design relative humidity should be 50% rh minimum or the design temperature equal to the outdoor air dew point design temperature, whichever is less.

Base Utilities - Describe the source of thermal energy that will be used (i.e. extension of central high pressure steam, hot water, natural gas, or stand alone heat source with the type of fuel utilized). Where more than one source of thermal energy is considered economically feasible, or where a facility is deemed appropriate for study as defined under the heading entitled “Energy Computations”, include a computerized LCCA to justify the selection. Show the proposed type and routing of the heat source conveyance system on the drawings, if applicable.

Heating System **-** Provide a description of the heating system proposed, including an explanation of why this system is preferred over others. Indicate locations of major components of the system. Resistance electricity and L.P. gas are not allowed for space comfort heating, except in unusual situations.

Ventilation System **-** State whether a gravity or mechanical system is to be used and provide a brief description of the ventilation system proposed. Indicate the outside air ventilation rates in cfm/person (L/s/person) for various room types. The prescribed rates must be in compliance with the latest edition of ASHRAE 62. Describe the operation of the ventilation system in summer and winter modes. Indicate the number of outside air changes per hour in various areas, the type of infiltration, and whether OSHA requirements are applicable.

Cooling System **-** Provide a description of the cooling system proposed including an explanation of why this system is preferred over others. Indicate locations of major components of the system. Identify special humidification or dehumidification requirements. Indicate ASHRAE Standard filter efficiencies and any other special filtration requirements.

HVAC Control System **-** Briefly describe the HVAC control system type and its functions. If applicable, indicate a requirement to tie into an existing Base-wide EMCS.

Energy Conservation – Briefly describe the mechanical system based on lowest life cycle cost. Provide a signed statement by a registered mechanical engineer indicating compliance with ASHRAE Standard 90.1-1999.

- **Plumbing Calculations**

Domestic Hot Water Heating – Calculate the hot water storage and demand requirements of the facility. Indicate the basis for the calculations including the incoming and storage water temperatures, the facility type, fixture types, fixture quantities, and the demand and storage factors.

Domestic Water Pressure Calculations – Determine the sufficiency of the water pressure available at the building to meet the required minimum fixture outlet pressure. Provide detailed pressure loss calculations including losses attributed to meters, fittings, pipe, backflow preventers, and pipe risers.

Domestic Hot Water Recirculation – Reference the plumbing code by which the domestic hot water recirculation rate is calculated. Calculate the recirculation rate and the recirculation pump head.

- **Mechanical Calculations**

“U” Factor Calculations – Use the latest edition of ASHRAE Standard 90.1 to determine the minimum “U” factors. Calculate “U” factors for all composite wall and roof systems using the latest edition of ASHRAE Fundamentals. Include cross sections drawings of all wall and roof systems to supplement the calculations.

Building Exhaust Calculations – Calculate exhaust requirements for removal of heat, fumes, dust, and vapors in various spaces as recommended by ASHRAE. If natural ventilation is proposed, provide calculations to support its use as a reliable means of ventilation.

Outside Air Requirements/Calculations – Calculate the outside air ventilation requirements as prescribed by the latest edition of ASHRAE Standard 62. Calculations must consider the factors of "Multiple Spaces", "Ventilation Effectiveness" and "Intermittent or Variable Occupancy" as specified in ASHRAE Standard 62.

Building Air Balance Calculations – Provide air balance calculations addressing the relationship between supply, return, outside air, and exhaust air quantities. Special requirements for space pressurization shall be reflected and referenced in the air balance calculations.

Heating and Cooling Load Calculations - Use of professionally recognized, nationally used computerized load calculations is required. Load calculations are required for each room or zone by the ASHRAE method indicated in the latest edition of the Fundamentals Handbook. Copies of input and output data are required. Psychrometric calculations shall be illustrated on psychrometric charts and submitted with the 100% submittal. Computer disks may also be requested (see 100% submittal requirements).

Duct Pressure Drop Calculations – Provide pressure drop calculations for all supply, return, outside and exhaust air systems.

1. All Variable Air Volume (VAV) supply duct systems shall be sized by the static regain method.

2. The static regain, equal velocity or equal friction methods may be performed on non-VAV supply duct systems.

Hydronic System Pressure Drop Calculations

Pipe Expansion Calculations

1. Provide pipe stress calculations for all low-pressure (15 psi) (kPa) steam, condensate and hot water piping systems where pipe diameters exceed 4 inches (100 mm) and/or the length exceeds 100 linear feet (30 m) without a directional change.

2. Provide pipe stress calculations for all medium and high-pressure steam and high temperature hot water systems.

Equipment Sizing Calculations – Provide equipment sizing calculations and psychrometric calculations and charts, if applicable, to justify the selection of equipment, including the following:

1. Terminal equipment including VAV boxes, fan coil units, etc.
2. Pumps.
3. Control valves and dampers.
4. Meters and metering devices.
5. Fans.
6. Air Handling Units.
7. Chillers.
8. Boilers.
9. Closed Circuit Coolers and Cooling Towers.

Heat Gain Calculations

1. Perform heat gain calculations for duct systems using 80% insulation efficiency.
2. Include heat gain from chilled water pumps on the chilled water system. Size terminal cooling coils with the effects of pump heat gain considered.

Duct Leakage Calculations – Calculate the expectant duct leakage based on the designer's requirements for the duct, seal, and leakage classes for each duct system using the latest edition of the SMACNA HVAC Air Duct Leakage Test Manual.

- ## Drawings

Drawings shall be sufficiently complete to indicate all aspects of installation. Where alternate methods or systems are intended, drawings must detail both alternatives. Judgement should be exercised to avoid overly congested drawings. When drawing congestion is likely, ductwork and piping should not be shown on the same plan.

- **Plumbing Drawings**

Demolition - "Demolition" plans should be separate and distinct from "new work" plans.

Orientation - Provide north arrows an all building and site plans. The orientation of plumbing drawings shall be arranged with the north arrow toward the top of the plotted sheets, unless overriding circumstances dictate otherwise. The orientation of all partial building or site plans shall be identical to that of the larger plan from which it is derived or referenced. Consistency in drawing orientation shall be maintained with all disciplines.

Legend – Provide legends to clarify all symbols and abbreviations used on the plumbing drawings.

Enlarged Plans – Enlarged plans shall be drawn at no less than ¼" = 1'-0" (1:50).

Riser Diagrams – Provide separate waste and water riser diagrams for all fixture groupings. All riser diagrams shall be drawn 3-dimensional (flat, 2-dimensional risers are unacceptable) and shall account for all pipe directional changes indicated on the floor plans.

Plumbing Fixture Schedule – Provide a fixture schedule utilizing fixture designations coordinated with the contract specifications.

- **Mechanical Drawings**

Demolition - "Demolition" plans should be separate and distinct from "new work" plans.

Orientation - Provide north arrows an all building and site plans. The orientation of mechanical drawings shall be arranged with the north arrow toward the top of the plotted sheets, unless overriding circumstances dictate otherwise. The orientation of all partial building or site plans shall be identical to that of the larger plan from which it is derived or referenced. Consistency in drawing orientation shall be maintained with all disciplines.

Legend – Provide legends to clarify all symbols and abbreviations used on the mechanical drawings.

Design Conditions – Provide a schedule indicating indoor and outdoor design temperatures for each room type.

Floor Plans – Exercise judgement to avoid overly congested drawings. When drawing congestion is likely, ductwork and piping should not be shown on the same plan.

Sections and Elevations – Provide as required to supplement plan views.

Enlarged Plans - Mechanical rooms should be drawn at no less than ¼" = 1'-0" (1:50). Congested mechanical rooms shall be drawn at no less than ½" = 1'-0" (1:20). Mechanical room plans should be supplemented by at least one section; at least two sections for more complex, congested applications.

Schematic Diagrams - A 3-dimensional isometric diagram shall represent mechanical room piping; flat, 2-dimensional risers are unacceptable.

Details – Details shall be edited to reflect the configurations and construction materials shown on the plans.

Equipment Schedules –

Controls - Control diagrams and sequences of operation shall be on the contract drawings, not in the specifications.

Site Work - Exterior above and below grade steam and condensate distribution and below grade chilled and hot water distribution plans shall be accompanied by profile drawings. Profile drawings shall clearly depict all other utilities in the proximity of the new work.

- # Design Submittals

  - ## 35% Design Development Submittal

    - **Basis of Design**

    - **Plumbing Drawings**

      Provide the following sheets, as a minimum, for the 35% drawing submittal:

      Plumbing Floor Plan – Show plumbing fixtures, floor drains and equipment locations.

    - **Mechanical Drawings**

      Provide the following sheets, as a minimum, for the 35% drawing submittal:

      Site Plan – Show connection to base steam distribution, location of propane and oil tanks, layout of ground coupled heat pump well fields, etc.

      HVAC Floor Plan – Show equipment locations, one or two-line duct layout and preliminary piping runs.

      Mechanical Room Plan – Show major equipment and maintenance access space.

    - **Calculations**

Provide the following calculations, as a minimum, accompanying the 35% submittal:

Energy Analysis – Provide a bound copy of the computerized energy analysis that includes input and output data in their entirety.

Life Cycle Cost Analysis – Submit the computerized LCC analysis utilizing the latest edition of the NIST Building Life-Cycle Cost Program.

Building Heating and Cooling Load – Provide a bound copy of the computerized load calculations with input and output data in their entirety.

ASHRAE 90.1 Compliance Calculations -

- **100% Prefinal Submittal**

  - **Drawings**

    Plumbing and mechanical drawings shall be complete to the extent that they may be released for bid as submitted.

  - **Calculations**

    Submit all calculations to support the plumbing and mechanical systems and the major equipment comprising those systems. The 35% Energy Analysis shall be updated with the equipment efficiencies scheduled on the drawings.

- **Final Submittal**

  - **Drawings**

    Submit the final plumbing and mechanical mylars.

  - **Calculations**

    Submit the final plumbing and mechanical calculations, revised and updated.